Journal of Bio-Environment Control, 20(3):221-226, (2011)

Effect of Breathable Film for Modified Atmosphere Packaging Material on the Quality and Storability of Tomato in Long Distance Export Condition

Mohammad Zahirul Islam[1], Young Shik Kim[2], and Ho-Min Kang[1,3]*

[1]Dept. of Horticulture, Kangwon Nat'l. Univ., Chuncheon 200-701, Korea
[2]Dept. of Plant Science and Technology, Sangmyung University, Cheonan 330-720, Korea
[3]Agriculture and Life Science Research Institute, Kangwon Nat'l. Univ., Chuncheon 200-701, Korea

Abstract. The study was carried out to investigate the effect of MA packaging materials on quality and storability of tomato in long distance export condition. We found that the fresh weight loss in perforated film was higher than other breathable films. The fresh weight of tomato (cv 'Madison') packaged with breathable films, such as 5,000 cc, 10,000 cc, 20,000 cc/m^2 · day · atm oxygen permeable films, reduced less than 0.6%, but perforated film that already being used for packaging horticultural crops showed 1.4% fresh weight loss during 5ºC storage for 20 days and then 20ºC storage for last 5 days with 85% relative humidity. The carbon dioxide and oxygen concentration in tomato packages showed proper level for MA storage in 20,000 cc/m^2 · day · atm O_2 breathable film treatment at 5ºC storage. Although at 20ºC storage, the carbon dioxide concentration increased sharply, the oxygen concentration decreased remarkably, the change of these gases concentration was the lowest in 20,000 cc film treatment. The ethylene concentration was sharply increased at 20ºC from 21st day to 25th day after 5ºC storage for 20 day, and the concentration was lower in 20,000 cc film treatment among the breathable film treatments. Until 20 days, at 5ºC storage all treatments did not exceed the marketability. However, the last 5 days during at 20ºC, the fruit appeared fungal rots and the quality rapidly decreased. The 20,000 cc/m^2 · day · atm O_2 permeability treated tomato performed higher firmness (9.56 N), vitamin C (16.31 mg/100 gFW), and soluble solids (7 ºBrix) than other breathable films at final storage day. The results suggest that the 20,000 cc/m^2 · day · atm O_2 permeable film treatment of tomato (cv 'Madison') performed the highest quality and storability of tomato for long distance exporting.

Key words : carbon dioxide, ethylene, firmness, oxygen, soluble solids, vitamin C

Introduction

The losses of postharvest quality mainly happen after harvesting to before consumption. The loss of quality is caused by physical, chemical (Cruz et al., 2009) and gaseous changes. This high loss is due to inadequate storage facilities along improper packaging and transportation (Kebede, 1991), and harvesting inappropriate maturity stage without considering the purposes, market place and destination, as well as consumer and buyer. Nowadays, breathable film is getting popularity as a packing material to export horticultural products as well as during display at outlet/super market. It helps to provide UV stability, slowing respiration rate, retarding spoilage, retain longer water molecules, inhibiting the dehydration process, retain freshness, extend self life and maintain high quality during storage period. Softening of fruit exposed to ethylene can reduce their storage life shipping ability (Kader, 1985).

Modified Atmosphere (MA) packaging usually use to maintain the optimum O_2 and CO_2 concentration that is product can gets long shelf life and maintain quality. Low oxygen (3~5%) atmospheres retard tomato ripening while high levels of carbon dioxide (> 5%) are considered damaging for tomatoes (Cantwell et al., 2009). Carbon dioxide concentrations higher than 5% may cause surface discoloration, softening, and uneven coloration (Leshuk and Saltveit, 1990; Sargent and Moretti, 2004).

The micro perforated polypropylene (PP) film relates

*Corresponding author: hominkang@kangwon.ac.kr
Received August 2, 2011; Revised August 18, 2011; Accepted September 14, 2011

to the field of packaging for respiring or biochemically active agricultural products such as fresh fruits, fresh vegetables, fresh herbs, and flowers and more particularly for use in modifying the flow of oxygen and carbon dioxide into and/out of a fresh produce container (Sohn et al., 2008). The flesh firmness of apples packed in micro perforated film during the storage period was significantly higher than that of apples packed in non-micro perforated film, and the level of soluble solids was also higher (Chung et al., 2008). Grapes packaged with 0.03 mm polyethylene film maintained berry firmness, soluble solid content, titratable acidity, and peel L value compared with control treatment (Yang et al., 2007). At 5°C, near ripe grape tomatoes were of marketable quality for 18 days (Cantwell et al., 2009). Nowadays, the Korean produced tomatoes are exporting to Hong Kong at 5°C conditions. The study was carried out to investigate the effect of packing materials on quality and storability of 'Madison' tomato in different storage temperatures to export long distance country.

Materials and Methods

Hydroponics grown light red maturity stage of fresh consumed tomato (*Lycopersicon esculentum* Mill. cv Madison) was treated different gas permeability packaging films that show 5,000 cc, 10,000 cc and 20,000 cc/$m^2 \cdot day \cdot atm$ O_2 permeability at 5°C for first 20 days and then at 20°C for last 5 days with 85% relative humidity. The Madison was suggested to proper cultivar for exporting because it showed higher firmness among 15 cultivars and the highest soluble solids among 6 European cultivars (Zahirul et al., 2010).

Carbon dioxide and oxygen concentrations were measured by PBI Dansensor Check Mate 9900 and ethylene concentration was measured by GC-2010 Shimadzu equipped with Wax column and a flame ionization detector (FID). The detector and injector to operate at 127°C and the oven were 50°C, and carrier gas (N_2) flow rate 0.67 mL/s (Park et al., 2000). The weight loss of tomato during storage period was measured by subtracting sample weights from their previous recorded weights and result presented as % of weight loss compared to initial weight.

Visible quality was observed on the scale of 1 to 5 (1 = very bad, 2 = bad, 3 = good, marketable, 4 = very good, and 5 = excellent) during 5°C storage. Five panel members were employed to perform the quality of tomato.

Firmness was measured using a Rheo meter (Sun Scientific Co. Ltd., Japan) with maximum force of 10 kg and a 6 mm diameter round stainless steel probe with a flat end. During measurement, tomatoes were placed on a plastic ring to keep upright. Penetrating force (N) through the skin of the tomato flesh and deformation (mm) values during penetrations were recorded.

The vitamin C measured by RQflex plus (Merck, Germany) with mg/100 g FW (Arvanitoyannis et al., 2005). The soluble solid measured by Refractometer (Atago U.S.A. Inc., U.S.A.) and results were read directly in °Brix. The titratable acidity measured by DL 22 Food & Beverage Analyzer (Metter Toledo Ltd., Korea) and the result to report as % citric acid.

Result and Discussion

The carbon dioxide concentration was lower in 20,000 cc/$m^2 \cdot day \cdot atm$ O_2 permeable film treatment than other breathable films. In all treatments, at 5°C from initial day to 20th day carbon dioxide concentration was lower than 20°C from 21st day to 25th day. At 20°C, carbon dioxide concentration was rapidly increased in all breathable film treatments (Fig. 1). As concern about carbon dioxide concentration for MA storage of tomato, 20,000 cc treatment was proper because tomato was classified lowest vegetable of maximum carbon dioxide tolerance concentration (Kader, 2002). At 20th day in 5°C, the only 20,000 cc film treatment show less than 2% the carbon dioxide concentration that is maximum tolerance concentration of carbon dioxide of tomato (Kader, 2002). At the final storage day, the 5,000 cc film treatment of tomato produced higher carbon dioxide concentration whereas 20,000 cc film treatment of tomato produced lower carbon dioxide concentration at 20°C.

The oxygen concentration was sharply decreased at 20°C from 21st day to 25th day. However, the oxygen concentration was almost similar of each treatment from 5th day to 15th day at 5°C storage (Fig. 1). As concern about oxygen concentration for MA storage of tomato, 20,000 cc film treatment was proper because the minimum oxygen tolerance concentration of tomato was reported to 3%

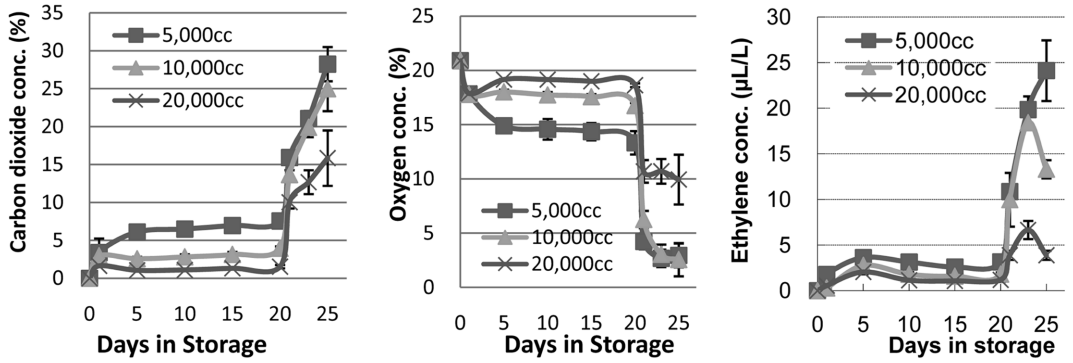

Fig. 1. Changes of carbon dooxide, oxygen and ethylene concentration of packages that had 5,000 cc, 10,000 cc and 20,000 cc/m^2 · day · atm O_2 permeability of light red maturity stage 'Madison' tomato at 5°C distribution temperature for first 20 days and at 20°C for last 5 days. Vertical bars represent ± SE of the means (n = 5).

(Kader, 2002). The recommended CA or MA condition of tomato was reported 3~5% carbon dioxide and 3~5% oxygen concentration (Saltveit, 2001). The 20,000 cc film treatment of tomato produced higher oxygen concentration and 10,000 cc film treatment of tomato produced lower oxygen concentration at the end of storage day at 20°C.

The ethylene concentration was sharply increased from 21st day to 23rd day and after that rapidly decreased at 20°C storage. However, at 5°C from initial day to 5th day storage in all treatments, the ethylene concentration was slightly increased and after that slightly decreased in all treatments until 20th day (Fig. 1). The ethylene was known the senescence induced plant hormone, also accelerated quality deterioration of tomato fruits, such as decrease of firmness and vitamin C and so on (Watada, 1986). The tomato fruit produced high level ethylene gas during ripening (Kays and Paull, 2004). The ethylene should be controlled lowest concentration in tomato packages. The ethylene concentration of 5,000 cc film treatment of tomato produced higher and 20,000 cc film treatment of tomato contained lower concentration at the last storage day.

As storage period progressed the fresh weight loss increased. At 5°C storage until 20th day the fresh weight loss was lower than at 20°C from 21st day to 25th day. Among all treatments, perforated film showed higher fresh weight loss at 25th day because of its pore. The higher fresh weight loss showed by perforated film and lower fresh weight loss showed by 20,000 cc film treat-

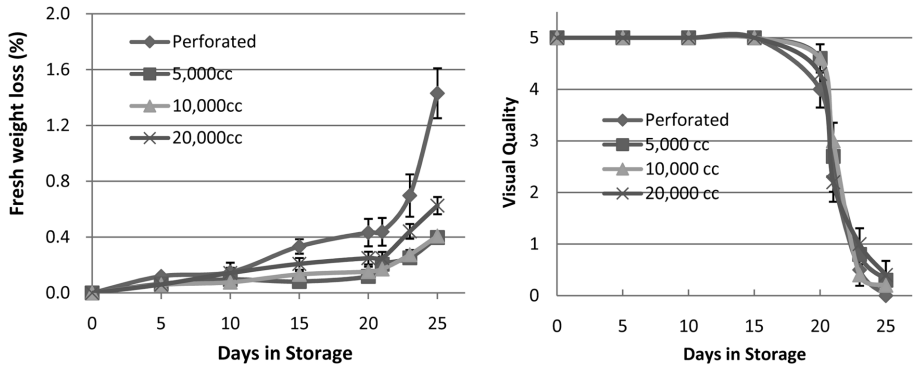

Fig. 2. Changes of fresh weight loss, visual quality of 'Madison' tomato packed with 5,000 cc, 10,000 cc and 20,000 cc/m^2 · day · atm O_2 permeability of light red maturity stage at 5°C distribution temperature for first 20 days and at 20°C for last 5 days. Vertical bars represent ± SE of the means (n = 5).

ment of tomato at 20°C at final storage day (Fig. 2). Until final storage day, our result did not exceed the maximum permissible weight loss 7% (Kays and Paull, 2004). During 5°C storage period, the fresh weight loss did not influence the fruit surface appearance due to control humidity and the fresh weight loss statistically significant at 1% and 5% level. These results indicate that the low temperature and packaging prevented the light red tomato from losing water as a result of transpiration, which prevented shrinkage of the tomato. Until 15 days in all treatments of light red maturity stage of tomato, the visual quality did not change and the marketable visual quality was remained until 20 days at 5°C storage (Fig. 2). At 20°C from 21st day to 25th day the visual quality rapidly decreased and the fruit appeared surface pitting and fungal rots.

Firmness is an important aspect of fresh consumed tomato fruit quality to export different countries. Usually, firmness decrease with advancement of storage period (Fig. 3). The 20,000 cc film treated tomato was contained the higher firmness than other treatments at final storage day, because firmness of climacteric fruit is decreased by ethylene (Kays and Paull, 2004) and 20,000 cc film treatments was maintained the lowest ethylene content among breathable film treatments during storage. But perforated film treatment that showed below 0.1 μL/L (data not shown) appeared the lowest firmness because it lost the highest fresh weight. The loss of moisture results in a reduction of fresh weight of the harvest product and losses in turgidity and firmness (Kays and Paull, 2004).

In addition, the 20,000 cc/m^2 · day · atm O_2 permeable film treated tomato showed the highest firmness, soluble solids and vitamin C content than other treatments, and the highest titratable acidity among breathable film treatments at the final storage day (Fig. 3). The soluble solids and organic acid that are primary respiratory substrates of horticultural crops might be maintained in proper CA or

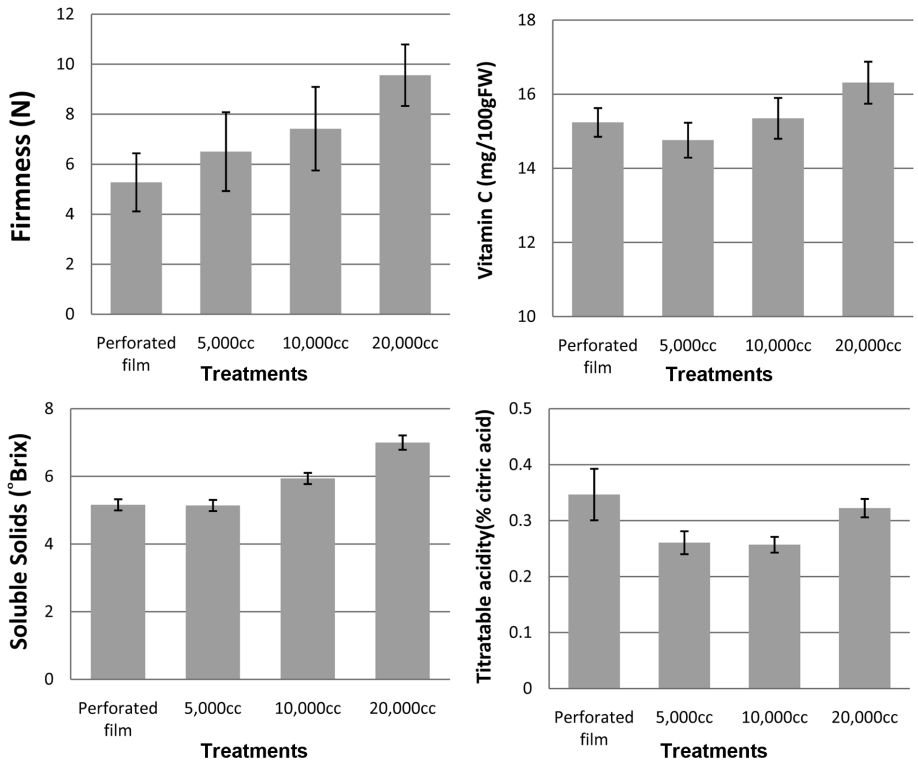

Fig. 3. Firmness, vitamin C, soluble solids, and titratable acidity of 'Madison' tomato packed with 5,000 cc, 10,000 cc and 20,000 cc/m^2 · day · atm O_2 permeability of light red maturity stage at 20°C distribution temperature at 25th day. Vertical bars represent ± SE of the means (n = 5).

MA conditions that should reduce respiration without any physiological disorder. The losses vitamin C content of horticultural crops is greater with increasing storage temperature and duration (Kays and Paull, 2004), and the vitamin C decreased sharply in improper storage condition (Lee et al., 1996).

The 20,000 cc/m^2 · day · atm O_2 permeable film treated 'Madison' tomato showed higher firmness, vitamin C and soluble solids than other treatments at the end of storage day. Therefore, the research result could be useful in helping to tomato growers and/ or exporters to export their tomato different countries by using breathable film packaging.

Acknowledgment

This study was supported by Technology Development Program for Agriculture and Forestry, Ministry for Food, Agriculture, Forestry and Fisheries, Republic of Korea.

Literature Cited

1. Arvanitoyannis, I.S., E.M. Khah, E.C. Christakou, and F.A. Bletsos. 2005. Effect of grafting and modified atmosphere packaging on eggplant quality parameters during storage. International Journal of Food Science and Technology 40:311-322.
2. Cantwell Marita, Xunli Nie, and Gyunghoon Hong, 2009. Impact of Storage Conditions on Grape Tomato Quality, 6th ISHS Postharvest Symposium, Antalya, Turkey. April 8-12, 2009
3. Chung, H.-S., P. Toivonen, and K.-D. Moon. 2008. Effect of modified atmosphere packaging in microperforated film on maintenance of the quality of fresh-cut apples, Korean J. Food Preserv. 15(3):346-351.
4. Cruz Rui M.S., C. Vieira Margarida, and L.M. Silva Cristina. 2009. Effect of cold chain temperature abuses on the quality of frozen watercress (*Nasturtium officinale* R. Br.), Journal of Food Engineering 94:90-97.
5. Kader, A.A., 1985. Ethylene-induced senescence and physiological disorders in harvested horticultural crops. Hort Science 20(1).
6. Kader, A.A. 2002. Postharvest technology of horticultural crops. 3rd ed. University of California, Division of Agriculture and Natural Resources. USA.
7. Kays J. Stanley and Paull E. Robert, 2004. Postharvest Biology. Exon Press, Athens,GA.
8. Kebede, E., 1991. Processing of horticultural produces in Ethiopia, Acta Horticulture 270(1):270-301.
9. Lee, S.K. 1996. Postharvest physiology of horticultural crops. Sungkunsa, Suwon (in Korean).
10. Leshuk, J.A. and M.E. Saltveit, Jr. 1990. Controlled atmosphere storage requirements and recommendations for vegetables. In: M. Calderon and R. Barkai-Golan (eds.). Food Preservation by Modified Atmospheres. CRC Press, Boca Raton, FL. Pp. 315-352.
11. Park, K.W., H.M. Kang, and C.H. Kim. 2000. Comparison of storability on film sources and storage temperature for fresh Japanese mint in MA storage. J. Bio. Env. Con. 9(1):40-46 (in Korean).
12. Saltveit, M.E. 2001. Postharvest Horticulture Series 22 in CD-ROM, University of California, Davis.
13. Sohn, I.B., Y.C. Noh, S.C. Choi, D.K. Ko, J.M. Lee, and Y.J. Choi, 2008. Femtosecond laser ablation of polypropylene for breathable film, Applied Surface Science 254:4919-4924.
14. Sargent, S.A. and C.L. Moretti. 2004. Tomato. Postharvest Quality Maintenance Guidelines. In, USDA Agric. Handbook 66. Commercial Storage of Fruits Vegetables and Ornamentals. K.Gross, M. Saltveit and C.Y. Wang, eds.). http://www.ba.ars.usda.gov/hb66/.
15. Watada, A.E. 1986. Effects of ethylene on the quality of fruits and vegetables. Food Technol. 40:82-85.
16. Yang, Y.J., Y.S. Hwang, and Y.M. Park, 2007. Modified atmosphere packaging extends freshness of grapes 'CampbellEarly' and Kyoho, Kor. J. Hort. Sci. Technol. 25(2):138-144 (in Korean).
17. Zahirul, I.M., T.J. Yoo, H.J. Jung, I.L. Choi, S.J. Jeon, J.H. Won, Y.S. Lee, Y.S. Kim, I.S. Kim, and H.M. Kang. 2010. The correlation and comparison of quality characters of several tomato cultivars grown by hydroponics. J. Bio. Env. Con. 19(2):88-92 (in Korean).

Mohammad Zahirul Islam, Young Shik Kim, and Ho-Min Kang

MAP 포장재인 숨쉬는 필름이 장거리 수출 조건에서 토마토의 품질과 저장성 향상에 미치는 영향

모하메드 조히를 이스람[1] · 김영식[2] · 강호민[1,3]*

[1]강원대학교 원예학과, [2]상명대학교 식물산업공학과, [3]강원대학교 농업생명과학연구원

적 요. 본 연구는 토마토 (cv 'adison')의 장거리 수출을 위한 MAP에 적합한 숨쉬는 필름을 구명하기 위해 실시하였다. 저장중 생체중 감소는 5,000cc, 10,000cc, 20,000cc/m^2 · day · atm의 산소투과도를 가지는 숨쉬는 필름 포장 처리구에서 0.6% 이하의 낮은 수준을 보인 반면, 기존에 원예작물 포장용으로 사용되던 천공필름은 1.4%의 감소를 보였다. 5ºC 저장중 포장재내 이산화탄소와 산소 농도는 20,000cc 필름처리에서 토마토 MA저장에 적합한 수준으로 유지되었다. 20ºC 저장에서는 이산화탄소 농도는 크게 증가하였고, 반면 산소농도는 급격히 감소하였는데, 역시 20,000cc 필름 처리에서 가장 변화폭이 적었다 포장재내 에틸렌 농도변화도 5ºC 저장 후 20ºC에서 저장한 21일부터 25일까지 크게 증가하였는데, 숨쉬는 필름처리 중에서는 20,000cc 처리에서 가장 낮았다. 토마토의 상품성은 5ºC 저장 20일까지 모든 처리구에서 유지되었으나, 20ºC 저장 5일째부터 곰팡이가 발생하면서 품질이 급격히 열화되었다. 저장 최종일에 분석한 경도, 비타민 C, 당도는 20,000cc 처리구에서 각각 9.56N, 16.31mg/100 gFW, 그리고 7ºBrix로 가장 높게 유지되었다. 이상의 결과로 볼 때, 20,000cc/m^2 · day · atm 산소 투과도를 가진 숨쉬는 필름이 20일 이상의 장거리 수출에서 적합한 MAP용 포장재라고 생각되었다.

주제어 : 경도, 당도, 비타민 C, 산소, 에틸렌, 이산화탄소